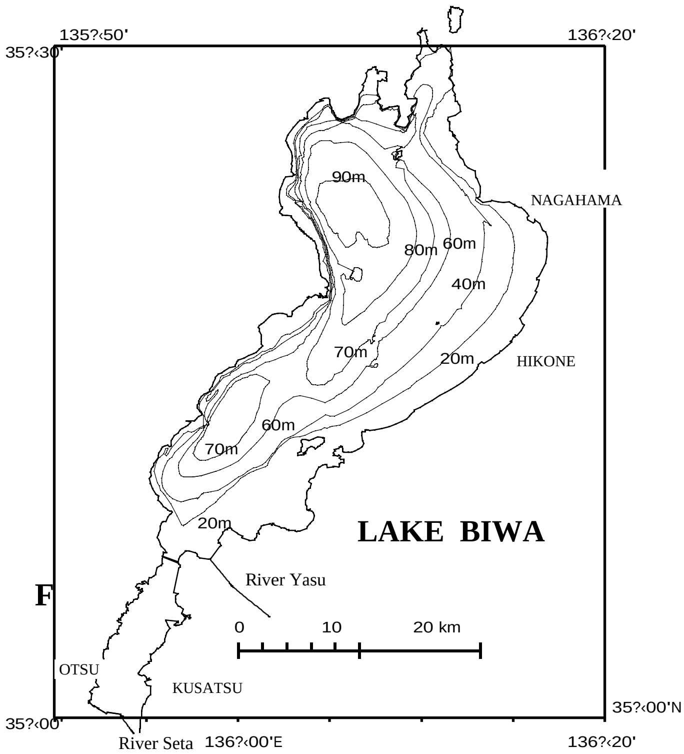
Physical Change of Lake Biwa and its Consequences

Shuichi Endoh
Faculty of Education, Shiga University
2-5-1 Hiratsu, Otsu, 520-0862. Japan.

Introduction

Lake Biwa (Fig. 1) is the largest lake in Japan and one of the oldest lakes in the world . It contains 273 x 10^8 m^3 water with a surface area of 680 km^2 and average depth of 40m. More than 1000 rivers with the watershed of 3840 km^2 drain into the lake, whereas lake water exits through the River Seta (the only outflow river) and a channel connecting with Kyoto City. The average residence time of the lake water is about 5 years, which is estimated from the annual discharge of about 50 x 10^8 m^3 (International Lake Environment Committee, 1987).

Fig. 1. Lake Biwa.



Lake Biwa has maintained a rich natural environment and ecosystem not only in the lake basin itself but also in the surrounding watershed. There are many endemic species living in the lake. The lake water is used for drinking, industry, agriculture and many other purposes by 14 million people in the Kinki megalopolis. During the last 20 years, the lake environment has been rapidly changed by development accompanying economic growth, water demand increase, and life-style changes within the watershed. Lake water quality has deteriorated due to eutrophication, and the integrity of the lake ecosystem has been destroyed year by year. This environmental degradation has caused serious problems such as red tides, algal blooms, and ecosystem change due to alien species invasion. This article introduces recent observational results on the environmental changes of Lake Biwa.

Water level depression

On the basis of recent meteorological data, the water budget in Lake Biwa basin was estimated (Fig. 2). During the last 20 years, the precipitation in the lake watershed has decreased from 1900mm to 1800mm perhaps due to the global warming. This water input decrease and recent unusual weather systems have caused an extraordinary water level depression especially in summer. For example, water level went down to 123cm below zero in 1994 and 97cm below zero in 2000. Such a low water level condition causes serious problems in water use and impacts upon the ecosystem in the lake.

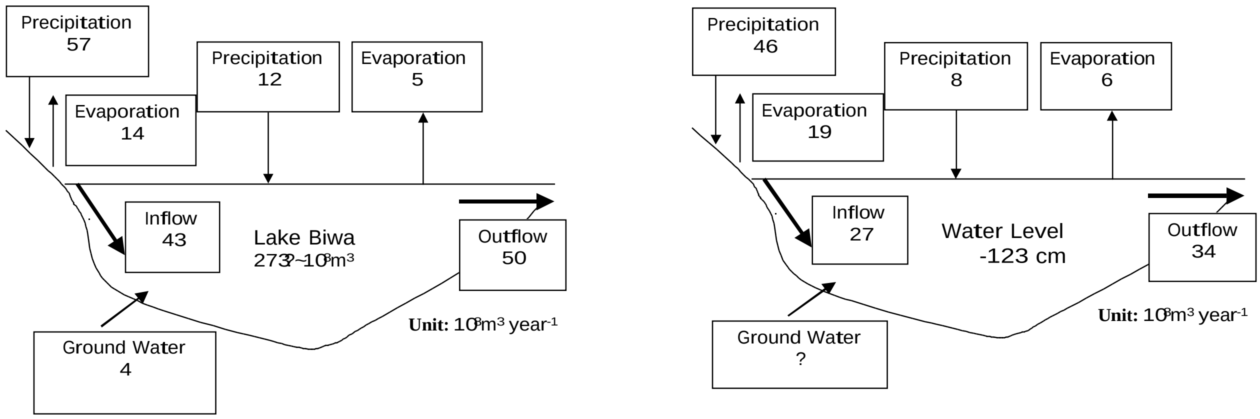


Fig. 2. Water budget in Lake Biwa basin; normal year (left) and in 1994 (right). Data derived from own measurements and those from Hikone Meteorological Observatory, Shiga Prefecture in 1993.

Recent warming of lake water

The global warming effect is also clear in the Lake Biwa watershed. Figure 3 shows the historical data of atmospheric temperature at Hikone City located on the eastern shore of the lake. The atmospheric temperature has increased about 1 ºC during the last 100 years.

Water temperature in the lake has also increased rapidly, especially in the last decade, undoubtedly caused by the global warming (Fig. 4). Deep water is now warmer due to successive warm winters in recent years. This warming of the lake water and the weakening of the overturn in winter may cause a serious problem to the lake's functioning.

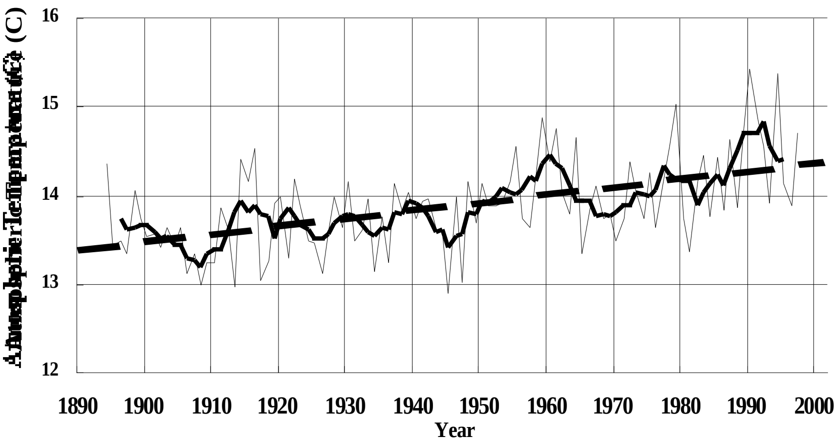


Fig. 3. History of annual mean atmospheric temperature at Hikone since 1894. Thick line represents a 5-year running mean, and dashed line indicates a linear regression.

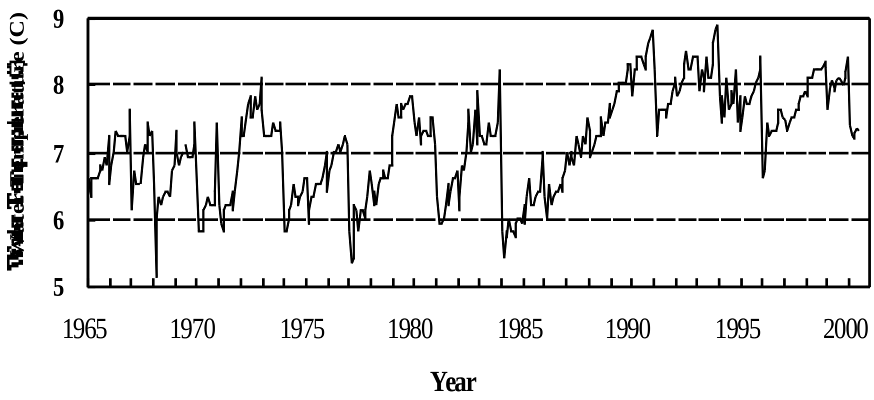


Fig. 4.
Seasonal change of water temperature at a depth of 70 m in Lake Biwa from 1965 to 2000.

River water inflow to the lake

The river water controls the lake water quality by the transportation of both dissolved and suspended materials into the lake. However, the behavior and the dispersion mechanism of the river water upon entering the lake are not clearly understood. Therefore, continuous observations were carried out to reveal the seasonal variation of the river water transportation into the lake. Attention was focussed on the River Yasu whose watershed area is largest among all rivers in the Lake Biwa watershed.

Figure 5 shows the seasonal changes of water temperature in River Yasu and Lake Biwa. It shows that water temperature of River Yasu is lower than the lake from autumn to spring, whereas it is higher from spring to early summer. During May and August, river water is warmer than lake water in the daytime but is cooler in the nighttime. From comprehensive analysis by using the water temperature data of the river and every 5m-depth in the lake, the seasonal change of inflowing depth of the river water was estimated. The result is shown in Figure 6. The river water intruded into the thermocline during summer and autumn, and into the bottom layer in winter. In early spring, the river water spread out on the lake surface. From these analyses, it is estimated that the exchange period of the lake water is about 20 years.

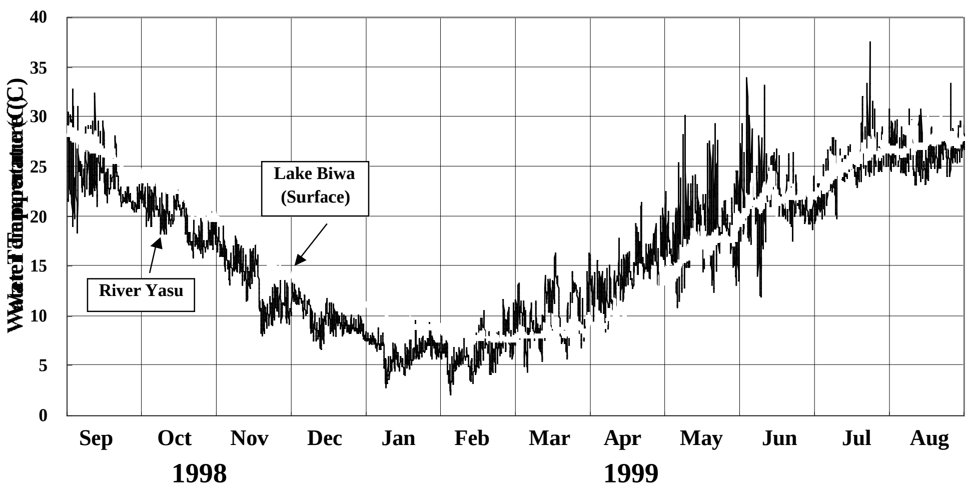


Fig. 5.
Seasonal change of water temperature in River Yasu and Lake Biwa (surface).

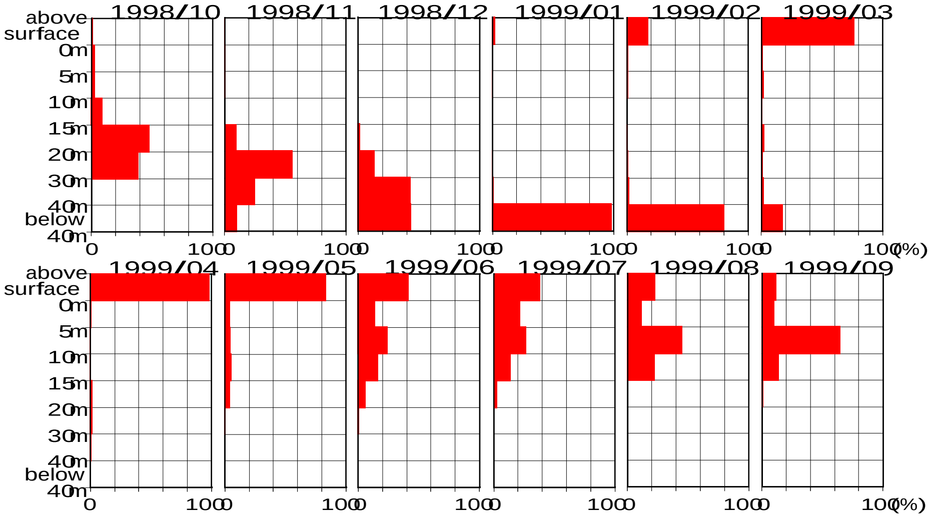


Fig. 6. Seasonal change of flowing depth of river water into Lake Biwa.

Benthic nepheloid layer

During the last decade, vertical and horizontal distributions of water temperature, turbidity, electric conductivity and Chlorophyll-a have been obtained both in the south basin and the southern part of the north basin of Lake Biwa. The benthic nepheloid layer (BNL), which is the layer just above the lake bottom with high turbidity, developed in the seasons of thermal stratification (Fig. 7), and was not detectable in the non-stratification period (winter). The BNL is maintained by organic matter sinking such as phytoplankton under decomposition. However, the turbidity in the nepheloid layer was much affected by the turbid water from rivers after heavy rainfall. In this case, the major component of the suspended substance in the nepheloid layer was inorganic soil. The particulate P concentration, which is originated from phytoplankton, also increased after rainfall. This suggests that phytoplankton in the surface layer sinks with clay and silt coming through rivers. From summer to the early winter, another kind of turbidity appeared in the bottom layer. This is caused by the chemical reaction of manganese under the anoxic condition. The resuspension of bottom sediment by strong currents also occurred, but it is not a major process for maintaining the BNL.

Discussion

It has been reported that the water quality of Lake Biwa has been almost stable during the last decade. However, there are many environmental and social problems associated with the lake. The alien species invasion, especially the releasing of some alien fishes has caused a rapid decrease of valuable endemic fishes and an increase of the sports fishing population. The high numbers of Great Cormorants has also caused serious environmental problems and is thought to have contributed to forest destruction and a downfall of the commercial fishery.

Recent water level depression is one of the most serious problems facing water management not only in Shiga Prefecture but also in Kinki megalopolis. The global warming effect in the lake basin should be carefully monitored focussing on lake water warming as well as the future trend of water evaporation. The warming of the lake water may also make water quality worse by the nutrient release from the sediment resulting from the reduction of the dissolved oxygen in the bottom layer. This may be caused by the combined effects of the decrease of vertical water mixing due to the warming of surface water and increasing demand for oxygen by the decomposition of phytoplankton that is predicted to increase due to the global warming trend.

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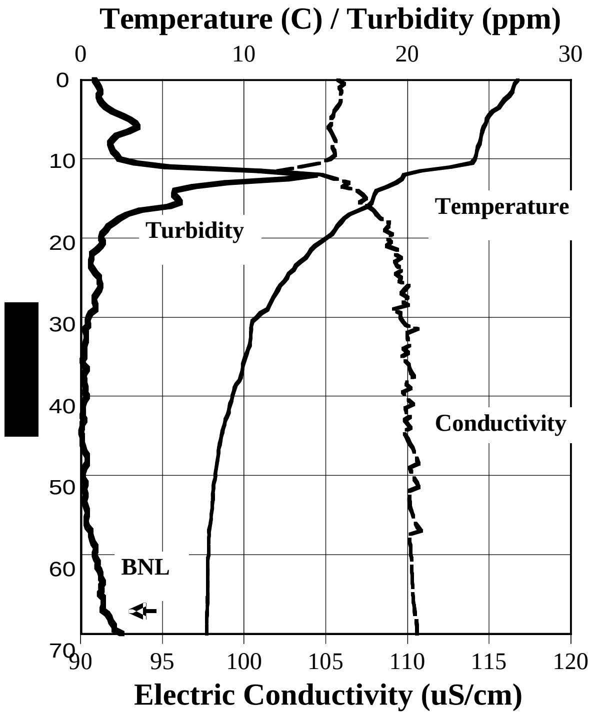

Fig. 7. Vertical profiles of water temperature, turbidity and electric conductivity.